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JP-8 and Other Military Fuels (2014 update)

Joel Schmitigal, Jill Bramer
TARDEC

17 June 2014

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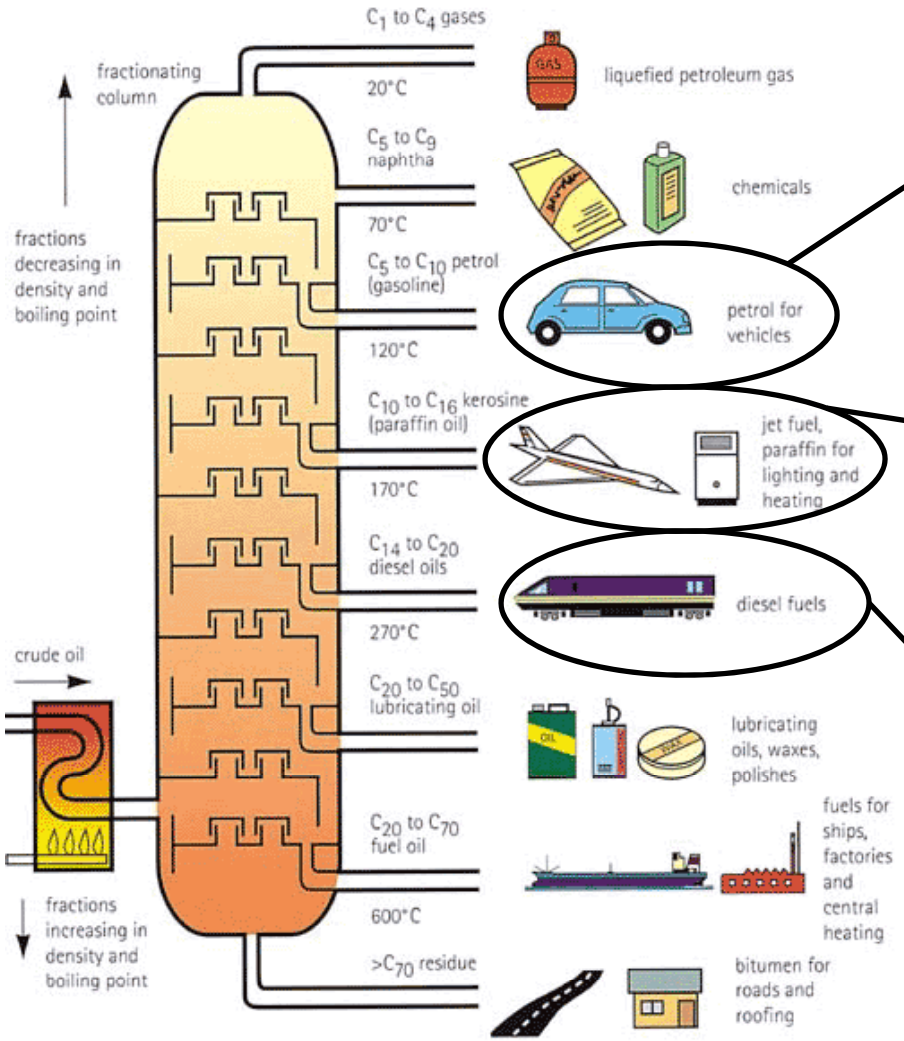
- What is JP-8?

- Why do we use it?

Petroleum Distillation



http://www.energyinst.org/

- Gasoline
  - Avgas ~0.690 kg/L
  - Mogas ~0.740 kg/L
- Kerosene Fuels
  - Jet Fuels
  - No. 1 Diesel
- No. 2 Diesel ~0.850 kg/L

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Commercial Aviation Fuels

- JET A - Kerosene cut of fuel normally only available in the U.S. for civil aviation use.
  - ASTM D1655
  - Freeze Point: ≤ -40ºC (- 40ºF)
  - Density @15ºC: 0.775 to 0.840 kg/L
  - Flash Point: ≥ 38ºC (100ºF)
  - 8 to 16 carbon atoms per molecule

- JET A-1 - Kerosene grade cut of fuel suitable for most turbine engine aircraft. It is produced to a stringent internationally agreed standard. It is widely available outside the U.S.
  - ASTM D1655, DEF STAN 91-91
  - Freeze Point: ≤ -47ºC (- 53ºF)
  - Density @15ºC: 0.775 to 0.840 kg/L
  - Flash Point: ≥ 38ºC (100ºF)
  - 8 to 16 carbon atoms per molecule

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Military Aviation Fuels

- JP-8 or NATO F-34 - Jet A-1 specification fuel containing military fuel additive package: static dissipater additive (SDA), corrosion inhibitor/lubricity improver (CI/LI), and fuel system icing inhibitor (FSII) and may contain antioxidant (AO) and metal deactivators (MDA). Single Fuel on the Battlefield used by the Army and Air Force per AR 70-12.
  - MIL-DTL-83133, DEF STAN 91-87
  - Freeze Point: ≤ -47ºC (-52.6ºF)
  - Density @15ºC: 0.775 to 0.840 kg/L
  - Flash Point: ≥ 38ºC (100.4ºF)

- JP-8+100 or NATO F-37 - JP-8 additized with +100 thermal stability improver additive (NATO S-1749).
  - Army – No Use Policy In Effect (Fort Rucker exception)
  - USAF – Issued Discontinuation Memo on 23 May 2014

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Military Aviation Fuels

- JP-5 or NATO F-44 - Kerosene based fuel that is the primary fuel for Navy shipboard aircraft operations containing military fuel additive package: SDA, CI/LI, FSII, (AO) and (MDA).
  - MIL-DTL-5624, DEF STAN 91-86
  - Freeze Point: ≤ -46ºC (-50.8ºF)
  - Density @15ºC: 0.788 to 0.845 kg/L
  - Flash Point: ≥ 60ºC (140ºF)

- F-24 – JET A with Military Additives – In 2012, a DoD CONUS conversion to F-24 was initiated. The conversion eliminated the use of JP-8 at CONUS military installations and replaced it with F-24. The effort will reduce the DoD cost to purchase fuel and simplify the logistics of obtaining the fuel used by CONUS installations by allowing for Jet A fuel to be pulled off multiproduct pipelines; then additized at DFSPs.
  - Freeze Point: ≤ - 40ºC (-40ºF)

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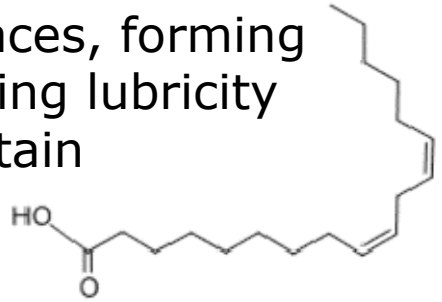
Military Fuel Additives

- Corrosion Inhibitor/Lubricity Improver (CI/LI) – Additive contains a polar group that adheres to metal surfaces, forming a thin surface film of the additive, thereby improving lubricity and inhibiting corrosion. Most CI/LI additives contain dilinoleic acid.



- Fuel System Icing Inhibitor (FSII) - FSII is chemically composed of di-ethylene glycol monomethylether (di-EGME) which contains both a hydrophobic (water hating) and hydrophilic (water loving) portion. This structure allows the molecule to be soluble in both nonpolar fuel and in highly polar water. Having a higher solubility in water the FSII works by combining with any free water that forms and lowering the freezing point of the mixture so that no ice crystals are formed. It also has bio-stat properties thus preventing bio-material from growing.

Military Fuel Additives

- Static Dissipater Additive (SDA) - Stadis® 450 increases the conductivity of the fuel, thereby increasing the rate of static charge dissipation.

- +100 Additive - Increases the thermal stability of the fuel by 100ºF to ~425ºF in an effort to prevent engine deposits caused by fuel being used as a heat sink. The additive is a combination of a dispersant, antioxidant, and metal deactivator, which prevents oxidation reactions and keeps potential insolubles in solution rather than depositing out on the engine surfaces.
  - Army NO USE POLICY - *The currently used +100 additive has a Dispersant/Detergent component that affects Army fuel/water separators increasing risk of water to enter fuel tanks. In addition, no benefit has been identified for Army systems*.
  - Air Force Discontinued use as of 23 May 2014.

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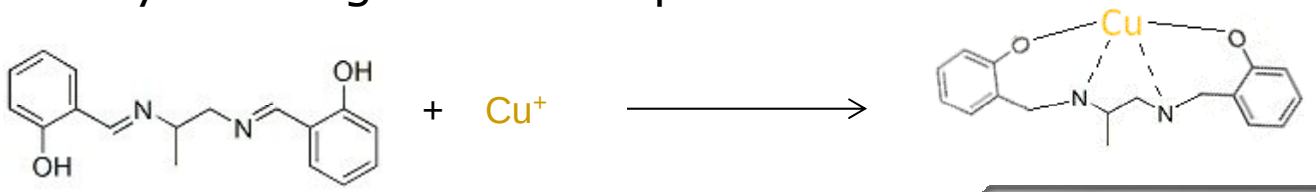
Military Fuel Additives

- Antioxidants (AO) - Required in military fuels that have hydrotreated components. Antioxidants improve storage stability by preventing the formation of peroxides, gums, and insoluble particulates. Peroxides attack elastomeric fuel system parts, gums can cause engine deposits, and insoluble particulates can cause engine wear and plug fuel filters. AOs function as hydrogen atom donors that stop the oxidation process. (F-24 is not required to have AO)

- Metal Deactivator Additive (MDA) - The only approved metal deactivator is N,N´-disalicylidene-1,2- propane diamine. Metals like copper and zinc can act as catalysts for oxidative reactions of fuel. MDA inhibits the catalytic activity of the metals by creating stable complexes with the metal ions.



Other Fuels

- No. 2 Diesel Fuel or NATO F-54 - Middle distillate fuel used for automotive diesel and gas turbine engines.
  - ASTM D975
  - Density @15ºC: ~ 0.820 to 0.840 kg/L
  - Flash Point: ≥ 52ºC (125.6ºF)
  - 12 to 21 carbon atoms per molecule

- No. 1 Diesel Fuel or NATO F-44 - A special-purpose, light middle distillate fuel for use in diesel engine applications requiring a fuel with a volatility higher than that provided by No. 2 Diesel Fuel.
  - ASTM D975
  - Density @15ºC: ~ 0.775 to 0.840 kg/L
  - Flash Point: ≥ 38ºC (100ºF)
  - 8 to 16 carbon atoms per molecule

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Other Fuels

- TS-1 – Wide cut kerosene fuel supplied at all airports within the former Soviet Union and in some Eastern European countries.
  - GOST 10227
  - Freeze Point: ≤ -60ºC (-76ºF)
  - Density @15ºC: ≥ ~0.787 kg/L
  - Flash Point: ≥ 28ºC (82.4ºF)

- F-76 - distillate fuel used in shipboard diesels, turbines engines, and boilers, storage stability requirement of 24 months.
  - MIL-F-16884
  - Density @15ºC: 0.800 - 0.876kg/L
  - Flash Point: ≥ 60ºC (140ºF)

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Other Fuels

- Avgas - Aviation fuel for use in spark ignition piston-engine aircraft.
  - ASTM D910
  - Freeze Point: ≤ -58ºC (-72.4ºF),
  - Density @15ºC: 0.690 – 0.715 kg/L
  - 4 to 10 carbons per molecule.
  - Similar to Mogas except :
    - Composed of lighter distillation fractions that are more stable to oxidation
    - Lower vapor pressure than Mogas
    - Some grades still use Tetraethyl Lead additive to prevent engine knock
- Mogas - Automotive gasoline used in spark ignition engines.
  - ASTM D4814
  - Density @15ºC: 0.715 to 0.770 kg/L,
  - 4 to 12 carbons per molecule.

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Other Fuels

- JET B - A wide cut fuel covering portions of the gasoline and kerosene fractions of distillation. Used in cold climates where its better cold weather performance is required. Similar to JP-4 fuel.
  - ASTM D6615
  - Freeze Point ≤ - 50ºC (- 58ºF)
  - Density @15ºC: 0.751 to 0.802 kg/L
  - 5 to 15 carbon atoms per molecule.

- JP-4 or NATO F-40 - A distillate fuel covering the gasoline and kerosene fractions of distillation including military fuel additive package: SDA, CI/LI, FSII and may contain OA and MDA. In use by USAF from 1951 to 1996.
  - MIL-DTL-5624
  - Freeze Point: ≤ - 58ºC (-72.4ºF)
  - Density: 0.751 - 0.802 kg/L
  - 5 to 15 carbon atoms per molecule.

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Other Fuels

- F-65 - 50/50 blend of No. 2 Diesel fuel (F54) and aviation turbine fuel JP-5 or JP-8. The fuel mixture, termed “M1 fuel mix” was developed in 1981 after turbine power plant of the M1 Abrams tank experienced waxing and filterability problems in Germany. The fuel mixture reduces waxing tendency and the viscosity of the diesel fuel in cold temperature environments. This fuel has not been needed since the implementation of the Single Fuel Policy, i.e., JP-8

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Alternative Fuels

- 1st Generation Alternative Fuels
  - Largely made from edible sugars, starches, animal fats and vegetable oils
  - Food based crops
  - Examples: Biodiesel, Ethanol
  - Not cost competitive with fossil fuels
- 2nd Generation Alternative Fuels
  - Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK) and Hydroprocessed Esters and Fatty Acids (HEFA)
  - More highly refined or made from synthesis process to make fuel.
    - Largely made from inedible plant materials, agricultural, wood waste
    - Jatropha, switchgrass, camelina
- 3rd Generation Alternative Fuels
  - Genetically modified crops that have a carbon-neutral output
  - Must be processed using FT or HEFA process.
  - Example: Algal biofuels
- 4th Generation Alternative Fuels - ??

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1st Generation Alternative Fuels

- Biodiesel – a fuel comprised of mono-alkyl esters of long chain fatty acids derived from Vegetable oils or animal fats (Fatty Acid Methyl Esters, FAME).
  - DoD NO USE POLICY in tactical equipment for B20
  - ASTM D6751 – blend stock
  - B5 is allowed in ASTM D975
  - B6 to B20 allowed in ASTM D7467
  - Problems
    - Storage stability
    - Material compatibility
    - Cost
    - Water affinity and microbial growth

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2nd Generation Alternative Fuels

CTL / GTL / BTL / CBTL: All use Fischer-Tropsch Processes

Syngas manufacture

O2 / Air

Syngas CO + 2H2

Fischer-Tropsch Synthesis

H2O

Paraffins

Selective Hydrocracking

Product Separation

FT SPK

Very similar processes also used in traditional petroleum JP-8 Production

Deoxygenation & Hydrotreating

H2O CO2

Paraffins

Selective Hydrocracking

Product Separation

HEFA

Because of the similar end-processing, FT SPK and HEFA are chemically similar blendstocks

3rd Generation Alternative Fuels

Used with permission from Mark Rumizen, FAA

Synthetic Biology

Genetically Engineered Microbes

Fermentation

Jet Fuel-Like Product

Sugar

Alcohol Oligomerization

Fermentation

Dehydration

Olefins

Conventional Refinery Processes

Polymerization

Hydroprocessing

Jet Fuel-Like Product

Lignocellulose

Pyrolysis

Pyrolysis

Bio-Crude

Back Up Slides

Backup

- JPTS - Jet Propellant Thermally Stable is fuel specifically formulated and produced for use in the USAF U-2 aircraft.
  - MIL-DTL-25524
  - Freeze Point: ≤ -53ºC (-63.4ºF)
  - Flash Point: ≥ 43ºC (109.4ºF)

- JP-1 - First jet propellant specified by the U.S. military in 1944.
  - AN-F-32
  - Freeze Point: ≤ -60ºC (-76ºF),

- JP-2 - wide cut fuel covering portions of the gasoline and kerosene fractions of distillation specified in 1945.

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Backup

- JP-3 – Widecut wide cut fuel covering portions of the gasoline and kerosene fractions of distillation specified in 1947.

- JP-6 - Kerosene based fuel developed in1956 for the XB-70 Valkyrie aircraft.
  - MIL-J-25656

- JP-7 - A fuel created from special blending stocks to create a fuel with low vapor pressure, high thermal oxidation stability, and low volatility. Developed in SR-71 Blackbird in the 1960's.
  - MIL-DTL-38219

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Backup

- JP-9 - A high density synthetic fuel blend of Exo-tetrahydrodi (cyclopentadiene), Methylcyclohexane, and H-norbornadiene dimers, used in air launched cruise missiles. Replaced by JP-10.
  - Density @15ºC: 0.935 to 0.955 kg/L
  - Freeze Point: ≤ -54ºC (-65.2ºF)
  - Flash Point: ≥ 21ºC (70ºF)

- JP-10 - A high density synthetic fuel composed entirely or nearly entirely of Exo-tetrahydrodi (cyclopentadiene) used in air launched cruise missiles.
  - Density @15ºC: 0.935 to 0.943 kg/L
  - Freeze Point: ≤ -79ºC (-110.2ºF)
  - Flash Point: ≥ 55ºC (131ºF)

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